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ABSTRACT

A study investigated how comprehension, as measured by the accuracy and speed of performance, is affected by the information contained in a set of procedural instructions. Using instructions that were varied with respect to the mode of presentation (pictures, text, or pictures and text) and the degree of explicitness of operational information, 68 college students assembled a toy. The results showed that the use of instructions containing detailed (explicit) operational information led to greater accuracy in assembling the toy, while the use of instructions containing pictures led to greater speed. (Copies of the different types of instructions are appended.) (Author/FL)

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The Effects of Varying Procedural Instructions on Comprehension

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Abstract

The purpose of this investigation was to determine how comprehension, as measured by the accuracy and speed of performance, may be affected by the information contained in a set of procedural instructions. Using instructions that were varied with respect to the mode of presentation (i.e., pictures, text, or both pictures and text), and the explicitness of operational information, 68 college students were videotaped individually as they assembled a toy cart. The results showed that the use of instructions containing explicit operational information led to greater accuracy while the use of instructions containing pictures led to greater speed. These findings have important implications for the design of instructional materials.

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The Effects of Varying Procedural Instructions on Comprehension

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The Effects of Varying Procedural Instructions on Comprehension

Comprehending procedural instructions can, at times, be quite frustrating. These instructions are the kinds that are used for such diverse tasks as assembling models, sewing patterns, or cooking recipes. They constitute a large and important category of reading material that most adults and many children have often used.

Depending on the nature of the task, successful comprehension of such material may lead to building the hoped for model, sewing the expected dress, or baking the appropriate pie. A good indication, then, that individuals have understood or comprehended these instructions is if they are able to achieve the desired outcome described in the directions (Gibson and Levin, 1975). Failure to comprehend such instructions may range from disappointing a child expecting a fully assembled toy on Christmas to not being able to stay abreast of the latest technological advances in one's field. Comprehension of instructional materials, then, has far reaching ramifications for the reader and yet little is known about this comprehension process or the factors that may affect it. In the present study an attempt was made to remedy this situation. Specifically, the comprehension of instructional materials was investigated by focusing on one of the factors that may affect such comprehension, namely, the the nature of the instructional materials.

There are several attributes of these materials that may affect comprehension. Organization, semantic content, structural organization,

and modality have all been found to influence a reader's understanding (Stone, 1980). Many of the studies in this area, especially those dealing with modality, have yielded contradictory findings. An example of this is the research aimed at comparing the comprehension of procedural information presented in text alone, pictures alone, or both pictures and text. While results of some studies indicate that the use of text leads to better comprehension, as measured by the accuracy of performance (Booher, 1975; Fleming, 1979), results of other studies suggest that either pictures alone (Crandell, 1979) or a combination of pictures and text (Stone and Glock, 1981) are more helpful.

One explanation for these discrepant findings stems from a methodological weakness of much of this research. That is, few of the textual and pictorial materials used in these studies were ever adequately described. In order to remedy this problem, Bieger (1982) developed a taxonomy of the kinds of information available in such reading material. Applying this taxonomy, Bieger found that comprehension can be affected by the information contained in a set of procedural instructions.

It is possible, then, that the contradictory findings relating to comprehension and presentation mode may be attributed to differences in the information content. In previous studies, certain kinds of information might have been more explicitly specified in either the text or the illustrations. For example, if the text included specific information on how to perform certain operations and the pictures displayed more general information, use of the text might have led to greater accuracy. On the other hand, if the pictures included the more

explicit information then they might have been associated with more accurate performance.

A comparison of the instructions used by Stone and Glock (1981) with those used by Crandell (1979) supports this idea. While the different sets of instructions were similar, one specific type of information, the operational or 'how to' information, was not included with the same degree of specificity. Bieger has found that this particular category of information is one of three criterial categories containing the necessary and sufficient information for the successful completion of an assembly task. In general, the illustrations used in Stone and Glock's research lacked detailed operational information, while those in Crandell's work contained such detail. This difference could explain why, for the same task, Stone reported less effectiveness of pictures than did Crandell.

The conflicting findings in the literature, then, may be due to differences in the amount of operational information contained in the various sets of procedural instructions. Thus, in the present study, it is expected that systematically varying the operational information in such instructions should affect the reader's comprehension of this material. Specifically, it is hypothesized that the inclusion of explicit operational information should facilitate the comprehension of procedural instructions. Readers using instructions containing explicit information are expected to comprehend these directions better than those using more general instructions.

Method

Subjects

Sixty-eight students, 41 females and 27 males, participated in this study. All were volunteers recruited from several introductory psychology courses taught at Cornell University.

Equipment and Materials

The equipment included a JVC Model G-71USJ color video camera and a JVC Model HR-2200U portable color video cassette recorder. An RCA Model TC1440B video date generator was connected to this equipment enabling the date and time to appear as part of the video signal. In this way, a continuous record of the subjects' assembly times was displayed on the television monitor.

The materials consisted of parts from the Fisher-Technik 100 model kit and sets of printed instructions for the construction of a toy loading cart. The Fisher-Technik kit is composed of colorful, plastic pieces that slide or snap together. When assembled, the toy loading cart is approximately 6.5 in. (16.51 cm) tall, 2.5 in. (6.35 cm) wide, and 2.5 in. (6.35 cm) deep.

The instructions included 16 individually mounted directions that were based on those created by Stone et al. (1981). However, unlike the Stone et al, instructions, the directions used in the present study were made to differ not only with respect to the mode of presentation (i.e. pictures, text, or a combination of the two), but also with respect to the amount of detailed operational information they contained. Since

three modes of presentation and two levels of operational information were varied, six sets of instructions were needed. As in the Stone et al. study, the three modes consisted of pictures alone, text alone, and a combination of both pictures and text. The levels of operational detail included an explicit or precise category and a less specific or general category. Thus, the operational information in half of the sets of instructions was explicit while the operational information in the other half was more general. In order to select appropriate instances of these levels, a preliminary analysis was undertaken to assess possible words and pictures that could be used to convey different degrees of operational information.

Using the sets of instructions designed by Stone et al., 12 graduate students were asked individually to judge the explicitness of various words that had been rated by a group of undergraduates as providing operational information. Based on a consensus among raters, two sets of textual ins ructions were then constructed. The set containing words rated as providing more explicit operational information is shown in Figure 1 while the other set containing words judged to be more general is depicted in Figure 2.

Insert Figures 1 and 2 About Here

In order to determine different levels of operational information in the pictorial instructions, two sets of 16 illustrations, based on those used by Stone et al. were drawn. In the explicit set, newly

introduced parts were depicted near to but not on their final location. Arrows were also included in these pictures as a means of showing where the parts were to fit. In the general set of illustrations, newly introduced parts were depicted in place. That is, a finished assembly was shown for each of the 16 pictures. The variations in these two sets of illustrations were chosen to reflect evaluations obtained from a sample of eight undergraduates.

After the new illustrations were drawn, two graduate students and one professional illustrator rated the explictness of the operational information included in both sets of instructions. Their evaluations and suggestions were then used to create the final versions of the explicit and general sets of illustrations shown in Figures 3 and 4 respectively.

Insert Figures 3 and 4 About Here

Procedure

Each student randomly received one of the six sets of instructions. The number of subjects in the six resulting instructional groups is shown in Table 1.

Insert Table 1 About Here

The students were briefed about the study and tested in a small, quiet room. To insure that all face and hand movements would be

adequately recorded, each performed the task seated at a large desk positioned in front of a camera. The experiment then proceeded as follows.

1. The students were told that they were going to build a model and could use the directions provided in any way that they wished. In addition, they were also given a separate sheet depicting the various parts and the names of those parts.

2. Since verbalization has not been found to affect performance on this task (Schorr, 1982), the subjects in the present study were asked to talk about what they were doing and why they were doing it. In order to accustom them to this idea of 'thinking out loud', all were requested to attempt a practice task before beginning the assembly of the loading cart.

3. Each was then videotaped individually as he or she performed the main assembly.

4. After the completion of the task, the students were interviewed and thanked for participating.

5. The time to completion and the accuracy of performance was noted for each subject.

Results

The hypothesis that the inclusion of explicit operational information in procedural instructions will facilitate comprehension was tested by performing a two factor ANOVA (2x3 design) for each of two measures of comprehension: number of errors made and time to completion. In order to support this hypothesis, significant main effects of

operational information would have to be found. As shown in Table 2, there was a significant main effect of operational information on the accuracy of students' performance ($F = 5.582$, $p<.05$).

Insert Table 2 About Here

This finding indicates that college students using explicit instructions made fewer errors than students using the more general instructions. On the other hand, as presented in Table 3, the main effect of operational information on time was not significant. The overall assembly time for students using explicit instructions was no different from the overall assembly time for students using the more general directions.

Insert Table 3 About Here

One factor that was found to affect assembly time, however, was the mode of instructional presentation. The significant main effect of presentation mode on the speed of performance, shown in Table 3, indicates that subjects using instructions containing either pictures, text, or a combination of the two took significantly different amounts of time to complete the task. The Tukey method of multiple comparisons was used to determine which presentation modes were different from the others.

The analysis showed that, regardless of the level of operational detail, subjects given the text only took significantly longer to perform the task than subjects given both the pictures only ($q = 9.06$,

$p<.01$), and pictures and text combined ($q = 7.09$, $p<.01$). These subjects, however, did not differ with respect to the number of errors left uncorrected ($F = 2.45$, $p>.05$). Thus, subjects using either pictures, text, or a combination of the two, made comparable numbers of mistakes (see Table 2).

There was one way, however, in which the presentation mode affected the accuracy of performance: different types of errors were found to be less prevalent in certain presentation modes. In the p:esent study, five kinds of errors were observed: 1) location or the attachment of parts to an incorrect area of the model, 2) orientation or the placement of parts in the proper location but in an improper orientation, 3) omission or the failure to use all of the parts, 4) unsturdy construction or an inadequate assembly of the parts, and 5) unassembled areas or the failure to build or attach all of the sections of the model.

Analyses were conducted to determine whether any of these mistakes was made by a different proportion of college students using either pictures only, text only, or both pictures and text. The results of these analyses, presented graphically in Figure 5, show that significantly different proportions of subjects using the three types of instructions made four of the five kinds of errors. Two of these

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Insert Figure 5 About Here

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errors, orientation and location, were found to be made by a smaller proportion of subjects using pictures only ($\chi^2=7.05$, $p<.05$; $\chi^2=10.31$,

$p<.05$). While an equally small proportion of subjects using both pictures and text were found to have made orientation errors, the proportion of these subjects making location errors was just as great as those using the text only. Thus, the use of pictures, either with or without text, led to fewer errors of orientation while the use of pictures without text led to fewer errors of location.

In contrast, a significantly larger proportion of subjects using pictures was found to have made two of the other kinds of mistakes, omission ($\chi^2=10.46$, $p<.005$) and unsturdy construction ($\chi^2=10.61$, $p<.005$). Compared with those using the text alone or both the pictures and text combined, a greater percentage of subjects using the pictures alone was found to have committed these two types of mistakes. There were no significant differences, however, for the fifth type of error, unassembled areas.

Discussion

The hypothesis that the comprehension of procedural instructions would be aided by the inclusion of explicit operational information received partial support. When comprehension was measured by the number of errors left uncorrected, it was found that, regardless of the mode of presentation, students using instructions containing explicit operational information made fewer uncorrected errors than those using more general instructions. Thus, explicitness of operational information seems to improve the accuracy of performance. This finding supports Bieger's (1982) contention that operational information is one of the criterial categories of information contained in procedural

instructions.

When comprehension was measured by the time to completion, however, explicit instructions did not have the same facilitative effect. Students who used instructions containing explicit operational information did not take any less time to complete the assembly than students who used the more general instructions. Thus, while explicitness of operational information improves the accuracy of performance, it does not have the same beneficial effect on the speed of performance. However, since those using explicit instructions did not require any more time to complete the assembly than those using general instructions, there seems to be no disadvantage to the use of explicit instructions. The inclusion of explicit operational information, then, should help to improve both the pictures and text that are used in procedural instructions.

While explicitness of operational detail does not seem to affect the speed of performance, one factor that has been found to influence this speed is the mode of presentation. Findings from the present research as well as those from previous studies (Booher, 1975; Bieger 1982) indicate that readers are able to follow instructions quickly when these instructions include or consist of illustrations.

Illustrated instructions may also have an additional benefit. In the present study, for example, the spatial errors of location and orientation were less prevalent when pictures were used. It appears, then, that pictures may be better at communicating spatial information than words. Several reviewers have also commented upon the superiority of pictures in depicting spatial arrangements (Kolers, 1973; Schallert,

1980; Stone and Glock, 1981). Pictures, however, may not be superior in conveying other kinds of information. For instance, in the present study, errors of omission and unsturdy construction were more prevalent among the groups given pictures alone than among those given either text alone or text in combination with pictures. Thus, information relating to the details of construction seems to be better conveyed by words than by illustrations.

The evidence suggests, then, that when designing instructions one should include both pictures and text if it is important that a reader comprehend these directions quickly and accurately. Furthermore, as discussed above, the operational information contained in these instructions should be made to be as explicit as possible in order to ensure the greatest accuracy.

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Table 1

Instructional Groups

Operational Information Detail	Presentation Mode: Pictures Alone	Text Alone	Pictures and Text
Explicit	*N_c = 11	N_c = 11	N_c = 11
General	N_c = 11	N_c = 13	N_c = 11

* Number of College Students

Table 2

ANOVA Table for Number of Errors Made

Source	SS	df	MS	F	p
MAIN EFFECTS					
Presentation Mode	13.854	2	6.927	2.445	.095
Operational Information	15.812	1	15.812	5.582	.021
INTERACTION	9.509	2	4.755	1.678	.195
RESIDUAL	175.622	62	2.833		

Table 3

ANOVA Table for Time to Completion

Source	SS	df	MS	F	p
MAIN EFFECTS					
Presentation Mode	5666843.900	2	2833421.900	22.823	.0001
Operational Information	17732.592	1	17732.592	.143	.707
INTERACTION	742454.930	2	371227.460	2.990	.058
RESIDUAL	7697292.600	62	124149.880		

1. To build column: Connect three large blocks end to end. Attach a small block to the tab end of this structure.

2. To build column: Connect three other large blocks end to end. Attach the other small block to the tab end of this structure.

3. To form the back: Arrange the columns so that they are parallel with each other. They should be about the width of two blocks apart. (Be sure that the tabs at the end of each column point in the same direction.)

4. Connect the two columns by inserting four flat pieces between them. Slide each flat piece into place using the side grooves in the blocks. (All flat pieces should have their smooth sides on the same side.) They must be flush with the ends of the columns without tabs.

5. To build the axle assembly: Fasten one angle block to the end groove of column one and fasten the other angle block to the end groove of column two. (Be sure that the tabs of the angle blocks face the same direction as the smooth sides of the back.)

6. Slide the long rod through the two angle blocks.

7. To build the base: Fasten two large blocks end to end to form a short column. Attach a third large block to a flat piece by sliding the flared edge of the flat piece into a side groove of the block. (Be sure that the ends of the flat piece are flush with the ends of the block.)

8. Attach another large block to the other flared edge of the flat piece in the same way. (Be sure that the tabs of the blocks point in the same direction.)

9. Slide these two tabs into a side groove of the short column so that the side of the short column covers the ends of both large blocks and the end of the flat piece.

10. To attach the base to the axle assembly: Notice that the base has a column of two large blocks. One side of this column has a flat piece attached to it. Attach the opposite side of this column to the exposed tabs of the axle assembly. Be sure that the flat piece in the base has its smooth side up.

11. To form the wheel assemblies: Slide a washer over each end of a long rod so that they are flush with the angle block.

12. Slide a screw hub over each end of the long rod so that their threads point away from the angle blocks.

13. Next, slide a tire over each end of the rod. Next, slide a nut hub over each end of the long rod with their wings away from the screw hub. Screw the nut hubs and screw hubs together with the tires between them. Finally, slide a washer over each end of the long rod so that they are flush with the screw hubs.

14. To form handle one: Slide a short rod through a clip so that the clip is in the middle of the rod.

15. To form handle two: Slide another short rod through andother clip so that the clip is in the middle of the rod.

16. Next, the handles should be inserted in the end of the back with exposed tabs. Each handle should be inserted in the grooves at the front of the back so that the clips are resting against the ends of the blocks. The openings on one side of each clip should fit over the tabs at the ends of the columns. This completes the assembly of the loading cart.

Figure 1: Explicit Text

1. To complete column one: Assemble three large blocks end to end. Add a small block to the tab end of this structure.

2. To complete column two: Assemble three other large blocks end to end. Add the other small block to the tab end of this structure.

3. To create the back: Move the columns so that they are parallel with each other. They should be about the width of two blocks apart. (Be sure that the tabs at the end of each column point in the same direction.)

4. Attach the two columns by moving four flat pieces between them. Arrange each flat piece into place using the side grooves in the blocks. (All flat pieces should have their smooth sides on the same side.) They must be flush with the ends of the columns without tabs.

5. To create the axle assembly: Arrange one angle block on the end groove of column one and arrange the other angle block on the end groove of column two. (Be sure that the tabs of the angle blocks face the same direction as the smooth sides of the back.)

6. Locate the long rod through the two angle blocks.

7. To create the base: Assemble two large blocks end to end to complete a short column. Add a third large block to a flat piece by moving the flared edge of the flat piece into a side groove of the block. (Be sure that the ends of the flat piece are flush with the ends of the block.

8. Add another large block to the other flared edge of the flat piece in the same way. (Be sure that the tabs of the blocks point in the same direction.)

9. Move these two tabs into a side groove of the short column so that the side of the short column covers the ends of both large blocks and the end of the flat piece.

10. To add the base to the axle assembly: Notice that the base has a column of two large blocks. One side of this column has a flat piece attached to it. Slide the opposite side of this column onto the exposed tabs of the axle assembly. Be sure that the flat piece in the base has its smooth side up.

11. To create the wheel assemblies: Arrange a washer over each end of a long rod so that they are flush with the angle block.

12. Fasten a screw hub over each end of the long rod so that their threads point away from the angle blocks.

13. Next, arrange a tire over each end of the rod. Next, arrange a nut hub over each end of the long rod with their wings away from the screw hub. Adjust the nut hubs and screw hubs together with the tires between them. Finally, arrange a washer over each end of the long rod so that they are flush with the screw hubs.

14. To create handle one: Move a short rod through a clip so that the clip is in the middle of the rod.

15. To create handle two: Move another short rod through another clip so that the clip is in the middle of the rod.

16. Next, the handles should be moved into the end of the back with exposed tabs. Each handle should be moved into the grooves at the front of the back so that the clips are resting against the ends of the blocks. The openings on one side of each clip should fit over the tabs at the ends of the columns. This completes the assembly of the loading cart.

Figure 2: General Text

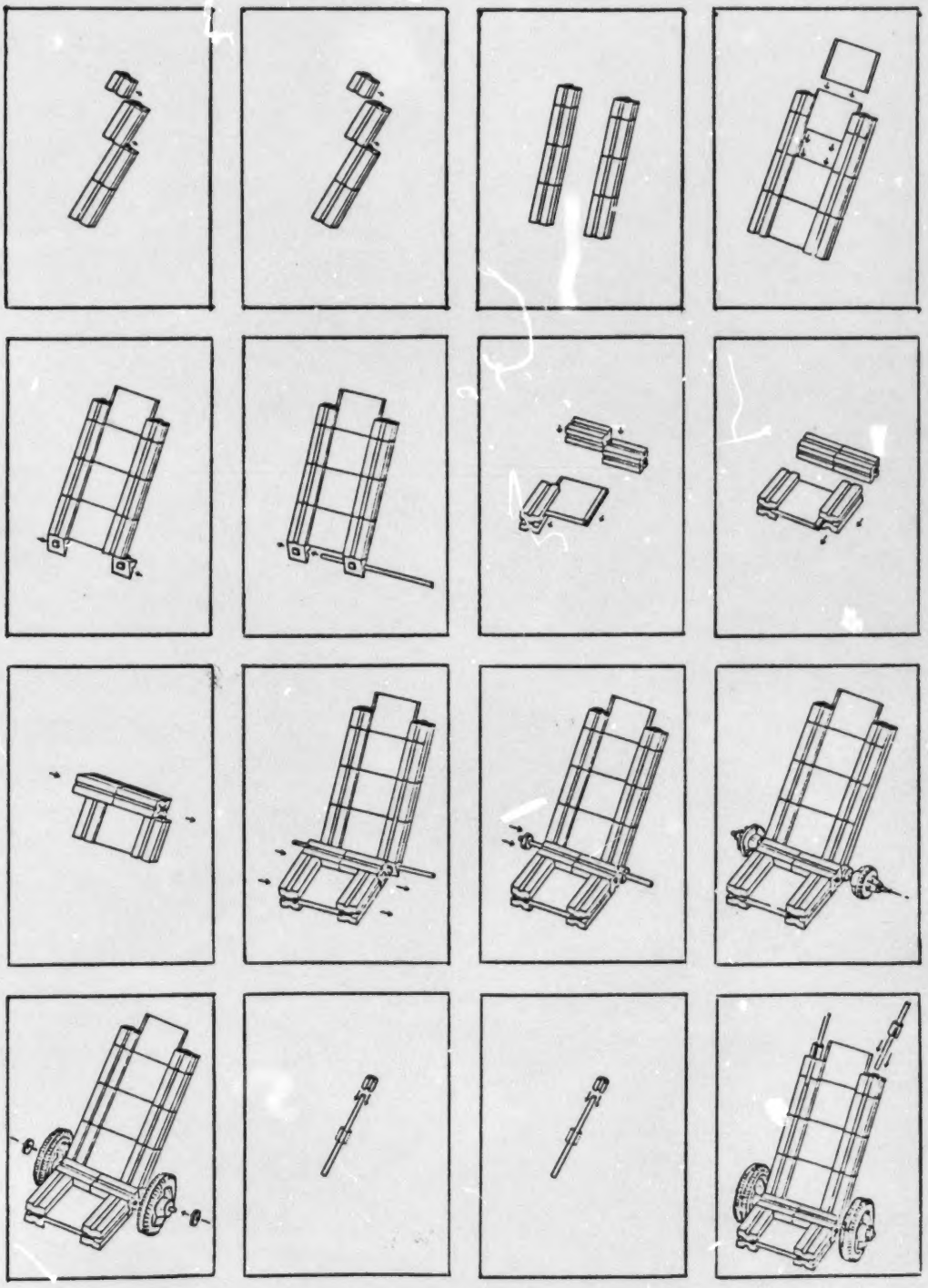

Figure 3: Explicit Illustrations

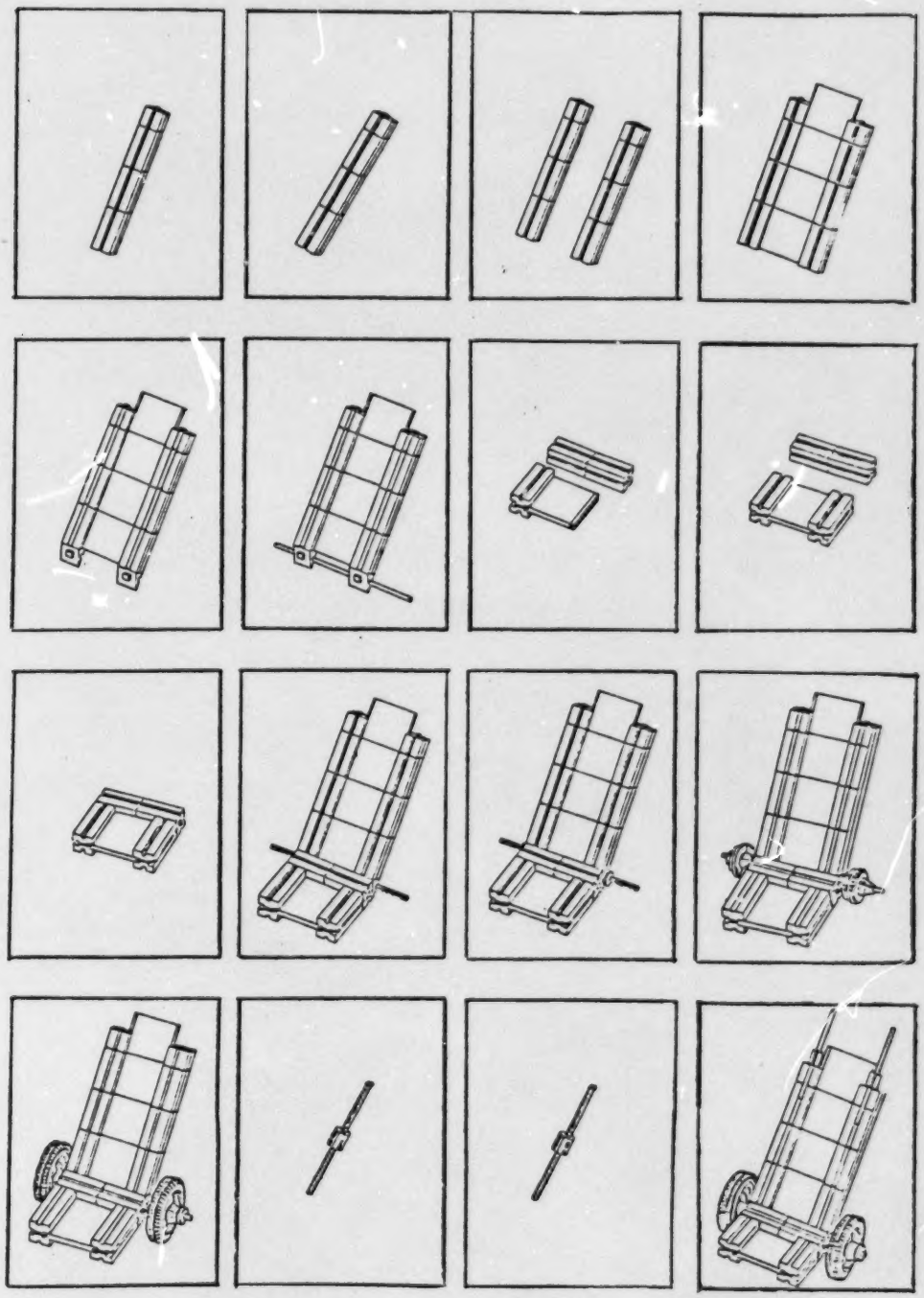

Figure 4: General Illustrations

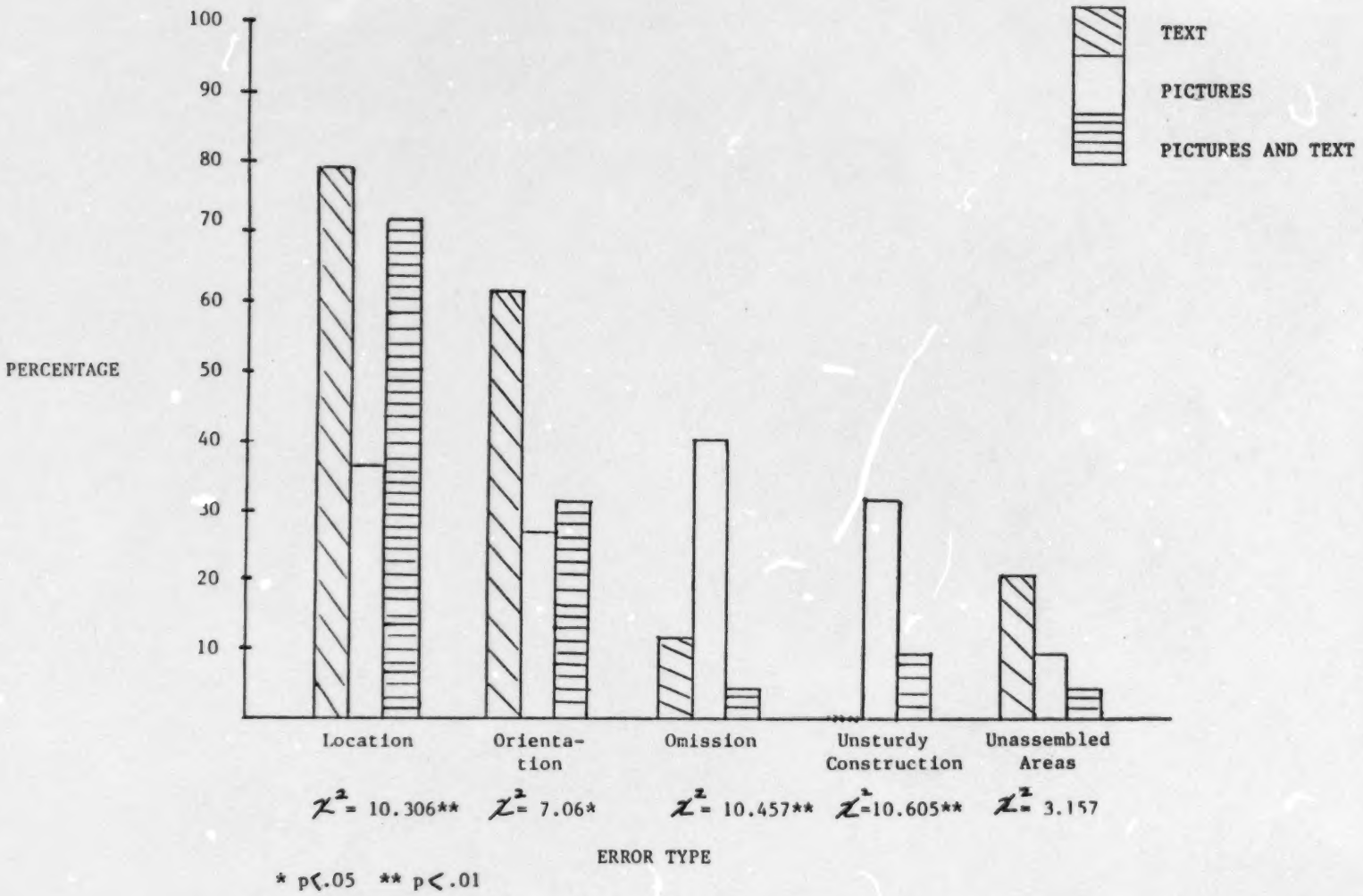

Figure 5: Comparisons of Error Types